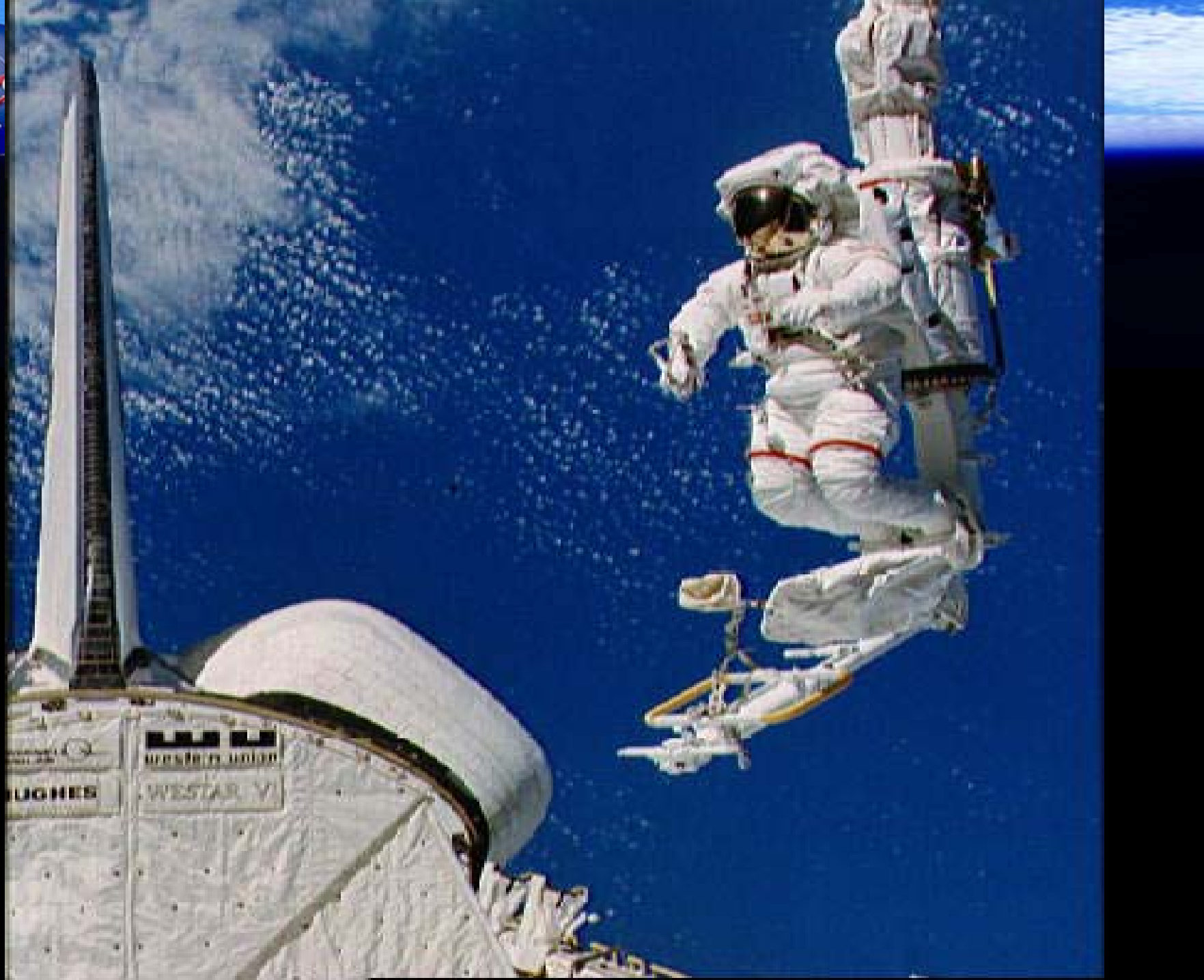
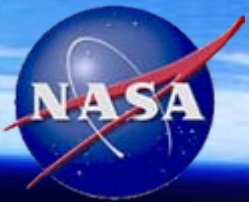




# **Health and Medical Risks in Exploration**

**Rich Williams MD, NASA Chief Health and Medical  
Officer**





temperature extremes

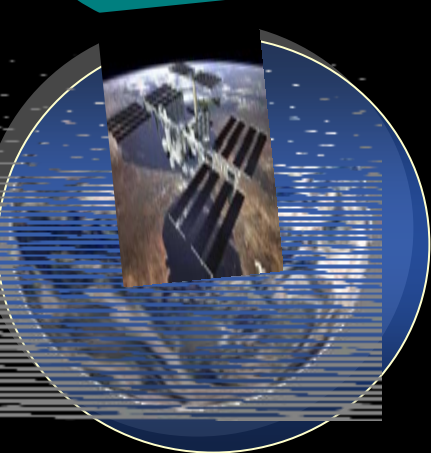
vacuum

Isolation & confinement

1 yr



$\mu g$



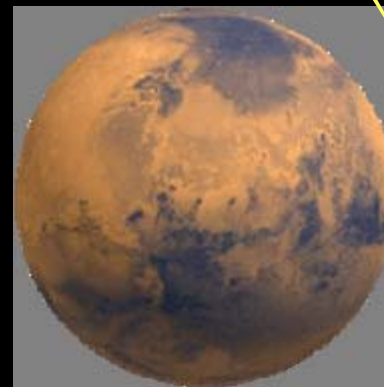
49,000,000 km

22 minute 1-way communication

Biorhythms?

circadian

$\mu g$



Water & food availability

New geo-ecosystem

Reduced gravity

Fuel & oxygen

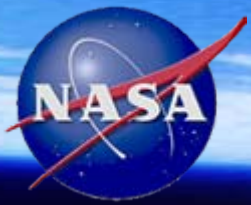
temperature extremes

vacuum

Isolation & confinement

1 yr

Radiation



# Analogue Environments

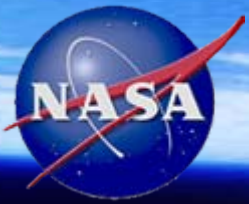


➤ *Where are the climbers ?*

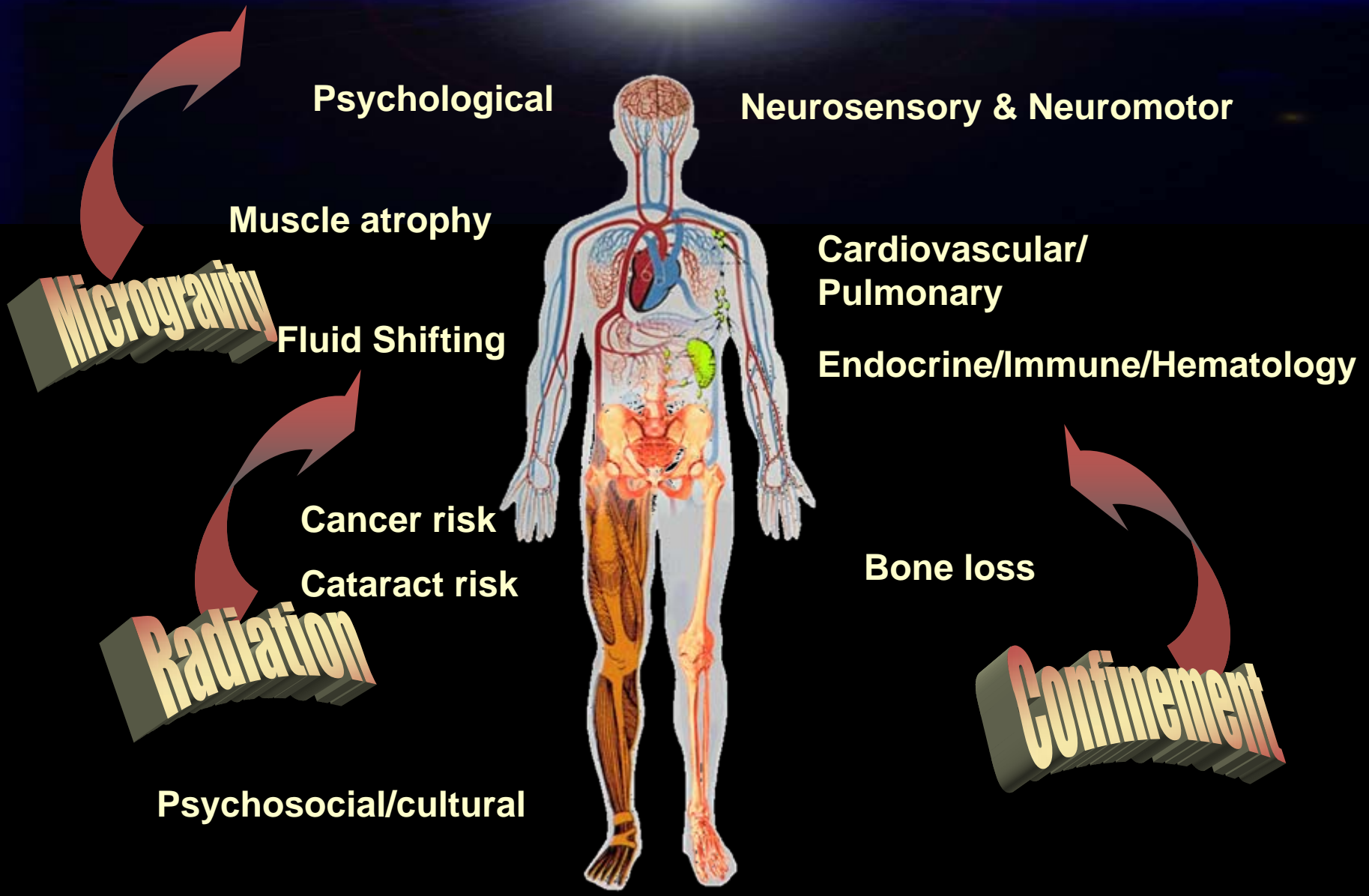
➤ *Are they moving?*

➤ *What is their heart rate?*

➤ *Are they becoming hypothermic?*



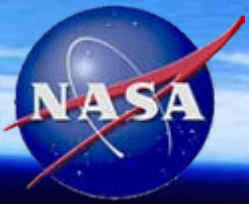
# *Physiology of Spaceflight*





# *Critical Risk Areas For Human Health*

- Radiation
- Bone Loss, Muscle Alteration and Atrophy
- Psychological Challenges
- Injury and Illness
- Space Motion Sickness
- Cardiac Physiology, Orthostatic Intolerance
- Immunology, Infection and Hematology
- Nutrition
- Neurovestibular Changes
- Circadian Disturbances



# *High Risk/Extreme Environment*

**Health emergencies may occur in flight as on the ground**

**Medical care highly limited**

**Short duration flight risks**

**Adaptation to microgravity**

**Psychosocial issues**

**Decompression sickness**

**Spacecraft decompression**

**Fire**

**Temperature extremes, radiation, toxicology**

**In flight medical problems**

**Long duration flight risks**

**Chronic debilitating or life threatening diseases**

**Health risks on return to Earth**

**Emergency egress liability**

**Re-adaptation to terrestrial environment/rehabilitation**



# *Space Medical Care: Illness and Injury in Space, US and Russian*

- *Heart rhythm disturbances*
- *Infections*
- *Toxic spills*
- *Physical fatigue: assistance required to ingress space station during EVA*
- *Irritated airway after a fire*
- *Burn injury*
- *Rapid cabin depression secondary to breach of hull*
- *Eye injury/irritation*
- *Dental problems*
- *Skin problems*
- *Fatigue: Contributor to Mir/Progress collision*
- *Possible Decompression Sickness (Bends)*
  - *Collins, Carrying the Fire: An Astronaut's Journey, Cooper Square Press, 1974*



# *Spontaneous Medical Events - Ground*

- *Cardiac Arrhythmias*
- *Angina*
- *Allergic reactions*
- *Ophthalmologic problems*
- *Appendicitis*
- *Diverticulitis*
- *Gallbladder disease*
- *Pancreatic inflammation*
- *Ulcers*
- *GI bleeding*
- *Spine problems*
- *Urinary stones*
- *Infections*
- *Hernia*
- *Joint problems*
- *Pneumonia*
- *Malignancies*

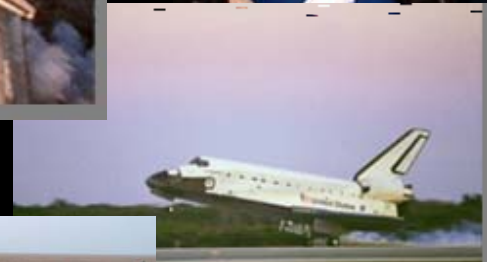
Adapted from: Johnston, et al, 2000  
(submitted for publication)



# *NASA Health Criteria*

Maintain health and well-being before, during, and after mission

Ensure rapid re-adaptation to gravitational forces





# *NASA Medical Care Criteria*

**Ability** to treat crew members  
and return them to duty

**Minimize** impact on remainder  
of crew

**Provide** for stabilization and  
evacuation (in LEO)

**Provide** for crew safety

**Provide** for remote  
consultation

**Provide** autonomous care





# *NASA Health Care Approach*

- Provide for healthy crews
  - *Emphasis on prevention*
  - *Selection criteria*
  - *Limited contact immediately before mission*
- Maintain health and well-being during a mission
- Stabilize and evacuate in cases of critical injury or illness in flight
- Ensure rapid re-adaptation to gravitational forces on return





# *Current Practice*

## *Pre-flight*

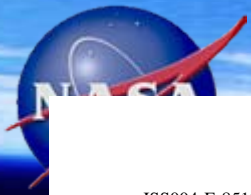
- Annual evaluations
- Preventive care
- Monitoring

## *In-flight*

- Daily Personal Medical Conference (PMC)
- Periodic health & environmental monitoring (also during critical mission operations)
- On-board crew medical officer
- Health maintenance measures as indicated, & follow-up

*Post-flight* • Care & follow-up until recovery





# *CPR in Space*

ISS004-E-8510 (11 March 2002) --- Astronaut Carl E. Walz, Expedition Four flight engineer, performs cardio-pulmonary resuscitation (CPR) on a jerry-rigged "human chest" dummy in the Destiny laboratory on the International Space Station (ISS).



ISS004E8510

ISS004-E-8504 (11 March 2002) --- Astronaut Daniel W. Bursch, Expedition Four flight engineer, performs cardio-pulmonary resuscitation (CPR) on a jerry-rigged "human chest" dummy in the Destiny laboratory on the International Space Station (ISS).



ISS004E8504

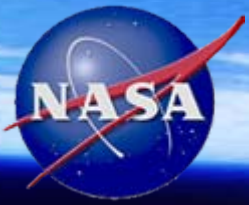


ISS004E8504

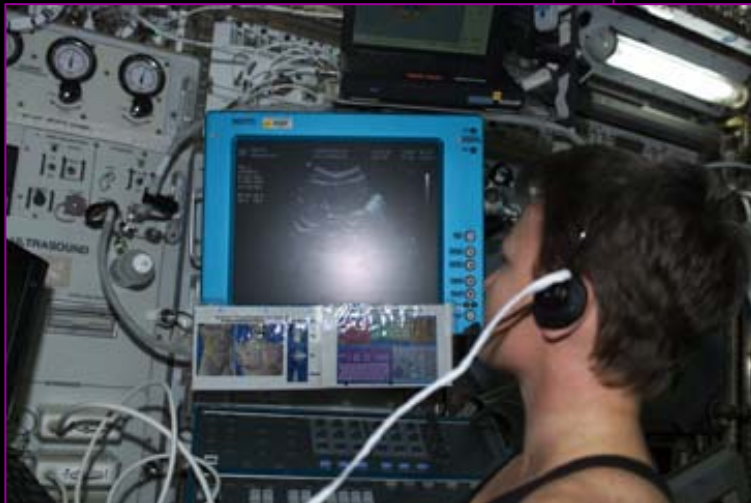
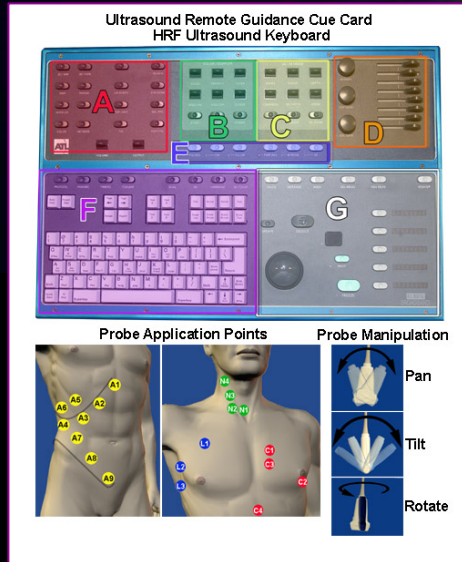


# *Space Medicine Ultrasound Training & Practice - Minimal (30-60 min)*





# Space Medical Care Development: Ultrasound for Diagnosis





# *Communications Factors*

**IMAGE  
DEGRADATION  
SATELLITE  
INTERRUPTIONS**

**SATELLITE  
DELAY (>2 sec.)**




**Voice  
Reference Files  
Procedures**

**Voice  
Real-time video (US)  
Real-time video (other?)  
Files (stills and cine)  
Recorded Video**




**PRIVACY**


# *Calling Earth*



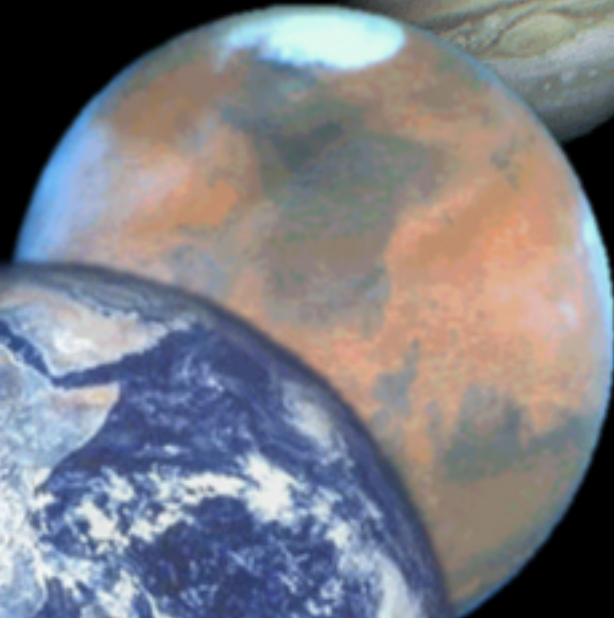
Mercury  
5-12 min.  
57 million km




Venus  
2-15 min.  
26 million km



Earth  
34-52 min.  
391 million km




Jupiter  
34-52 min.  
391 million km




Saturn  
71-88 min.  
795 million km

Uranus  
151-168 min.  
1693 million km



Neptune  
241-259 min.  
2706 million km



Pluto  
320-337 min.  
3573 million km

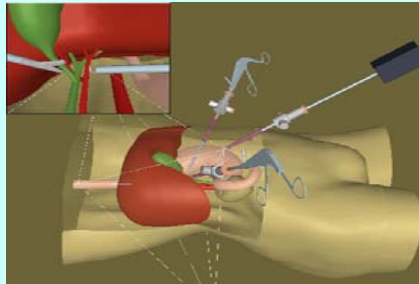
*\* Mean distances from Earth*

# Earth/Mars Telesurgery?



**Simulation**

**Virtual reality human**



**Surgeon**

**MEMICA Haptic-glove**

**Resulting surgery procedure**

**Telesurgery center**



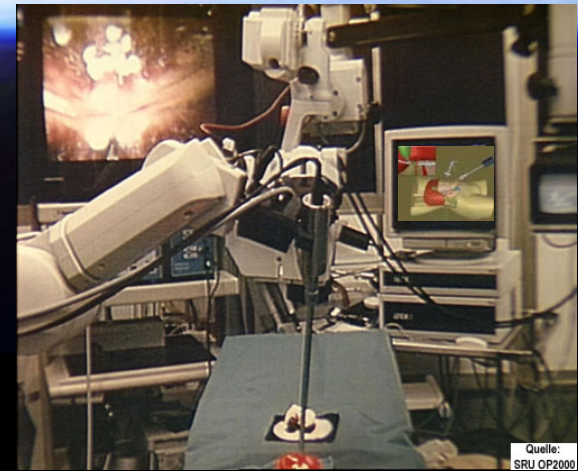
**Earth**



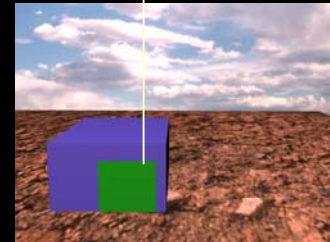
**Patient data**

**Medical Procedure Data**

**Robot performing surgery on the patient**



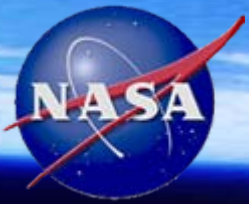
**Mars surgery center**



**Mars**



**55,7 Million Km ( 22 min.)**



# *Future of Health Care in Space: Exploration Class Missions*

## **From telemedicine to autonomous health care**

Adaptive Automation

Multipurpose Tactile Interface

Biosensors for environmental and  
physiologic monitoring

Genetic profiling

Genetic diagnosis

Genetic vaccines

Tissue engineering

Biologically-Inspired Robots

Biotech based immunotherapy

Functionally-Adaptive Biomimetics

Nanomachines

Cell herding, genetic surgery

Biologically based nanocomputers

Artificial intelligence

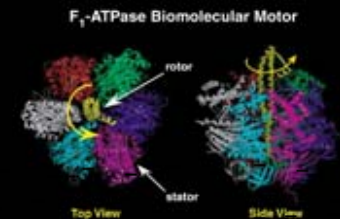
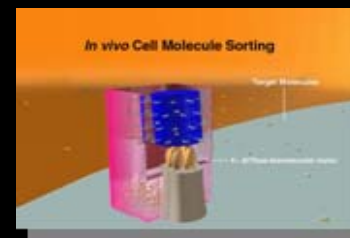
Smart/haptic systems

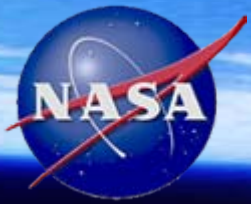
Virtual physician



**Hair cell sensors**

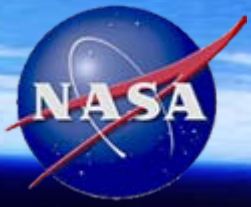
## **Biomotors**





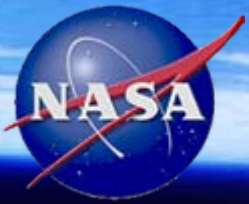
# *H&M Risk Management in Transformed NASA*

- CHMO as Independent Technical Authority
  - *Standards development and promulgation*
    - Standards serve as *de facto* declaration of acceptable risk
    - Standards serve as basis for biomedical research requirements and health related systems requirements
  - *Health related requirements review and concurrence/approval*
  - *Waiver authority*
    - Warrant system parallels that of Chief Engineer
  - *Review and approval of health related research deliverables for NASA medical practice*
- Office of Exploration Systems
  - *Biomedical research requirements development*
  - *Health related systems requirements development*
  - *Biomedical research/tech development products and deliverables*
  - *Systems development and acquisition*



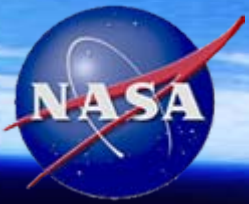
# *H&M Risk Management in Transformed NASA*

- Office of Space Operations
  - *Operates crew health system*
    - Provides care pre-flight, in-flight and post flight
    - Performs biomedical research in-flight, including validation of deliverables
  - *Assists in development of biomedical research requirements and systems requirements*
  - *Warrants*
- Health Systems Working Group
  - *HQ based cooperative effort*
  - *CHMO, OESD, OSO*
  - *Forum for coordinating all crew health related efforts at highest level*



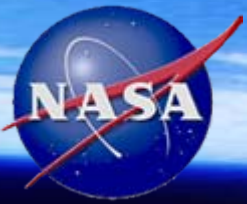
# *Health Standards Development*

- Parallels OSHA process
  - *Identify need for standard*
  - *Internal development, external review, approval*
- Permissible Exposure Limits
  - *Microgravity induced physiological changes*
  - *Radiation, Noise*
- Maximum Allowable Concentrations
  - *Toxicants, trace contaminants*
- Fitness for Duty Criteria
  - *Psychiatric/behavioral health concerns*
  - *Deconditioning*
  - *Task related*
- “Frame” level of medical care for exploration



# *Health Standards*

- Standards = foundation
- Requirements
  - *Biomedical research/development requirements*
  - *Systems requirements*
  - *Level of Medical Care*
    - Standard of Care
- Systems development/acquisition
- Systems operation
- Waiver authority
  - *Parallel Chief Engineer processes*



# *Bone Loss in Astronauts*

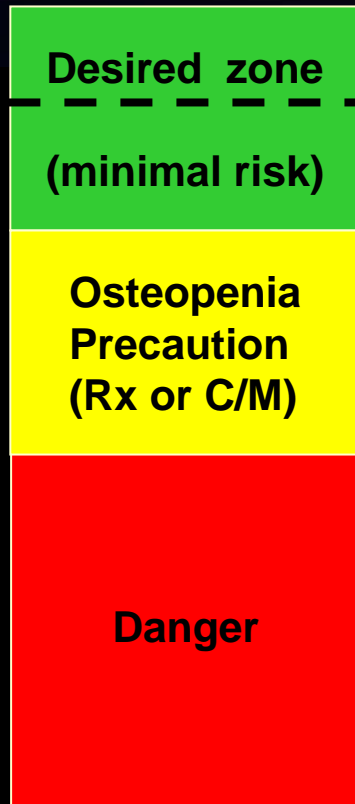
- Acceleration of age-related osteoporosis
- Fracture & impaired fracture healing
- Injury to soft connective tissue, joint cartilage, and intravertebral disc rupture with or without neurological complications
- Renal stone formation

*Note: bone formation and bone resorption are normally coupled on Earth and are thought to uncouple in space flight*



# *Osteoporosis - Definitions*

Typical 6 month  
space flight



+ 1.0 SD

100% of national  
average for age &  
sex related BMD

- 1.0 SD

- 2.5 SD

## Normal

- BMD is within +1 or -1 SD of the young adult mean

## Osteopenia (low bone mass)

- BMD is between -1 and -2.5 standard deviations below young adult mean

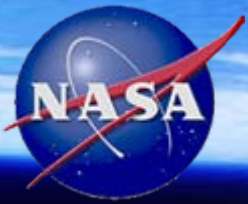
## Osteoporosis

- BMD is -2.5 SD or more than the young adult mean

## Severe osteoporosis

- BMD is more than -2.5 SD and one or more osteoporotic fractures have occurred

\* WHO definitions of osteoporosis based on DXA measurement at hip or spine



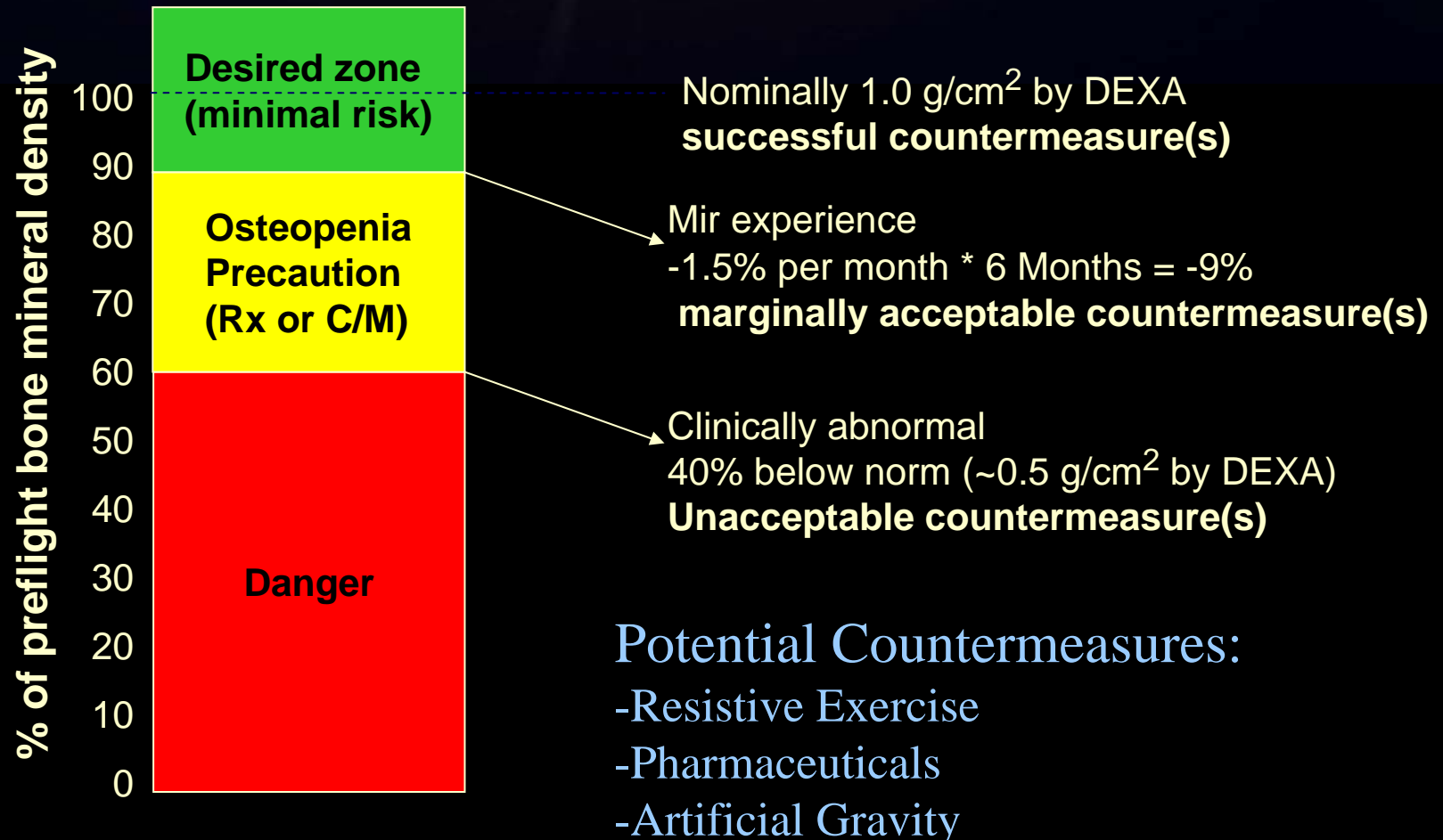
# *Osteoporosis Risk Factors*

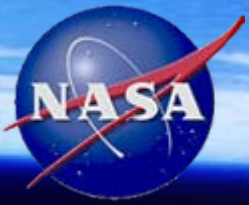
*(normal population)*

- Personal history of fracture after age 50
- Current low bone mass
- History of fracture in a 1st degree relative
- Female
- Thin and/or small framed
- Advanced age
- Family history of osteoporosis
- Estrogen deficiency as a result of menopause, especially early or surgically induced
- Amenorrhea
- Anorexia nervosa
- Low lifetime calcium intake
- Vitamin D deficiency
- Use of certain medications, such as corticosteroids and anticonvulsants
- Presence of certain chronic medical conditions
- Low testosterone levels in men
- Inactive lifestyle
- Current cigarette smoking
- Excessive use of alcohol
- Caucasian or Asian heritage

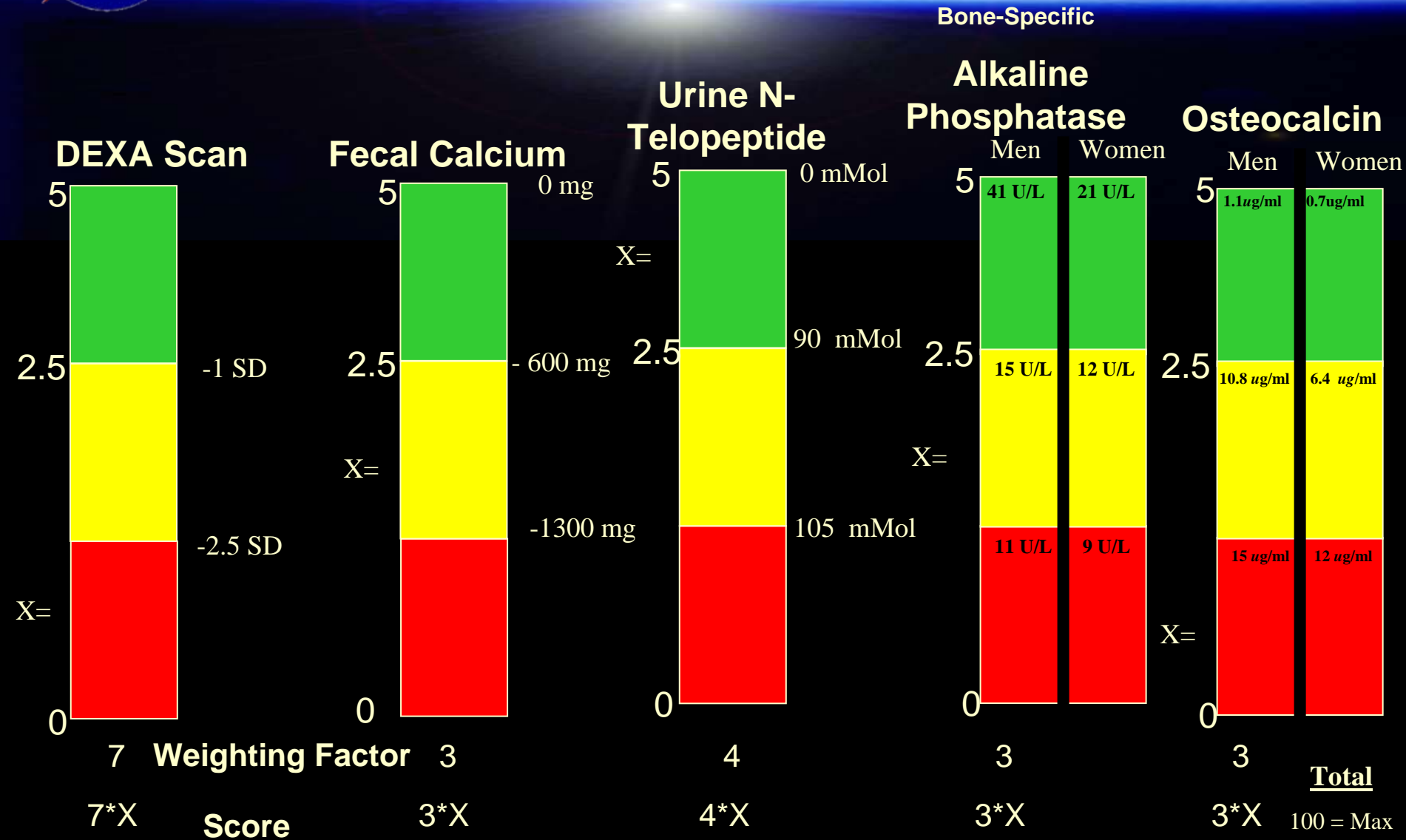


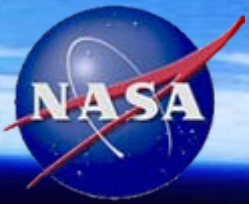
# *Example: Evaluation of Bone Countermeasure*





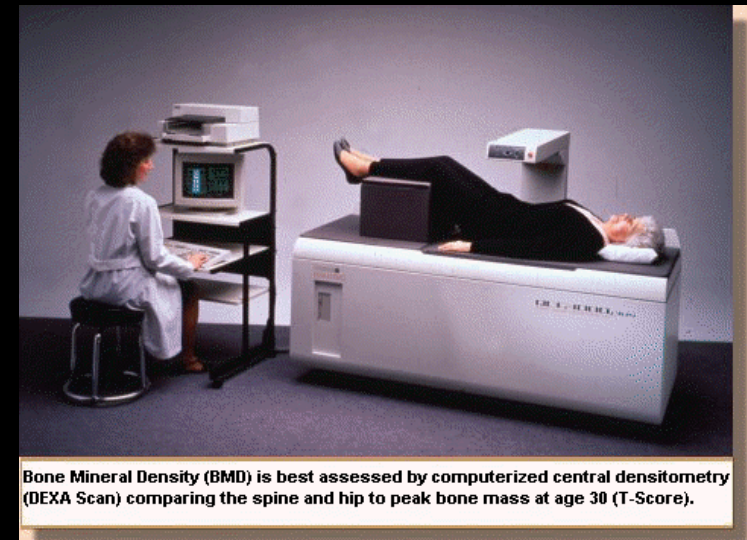
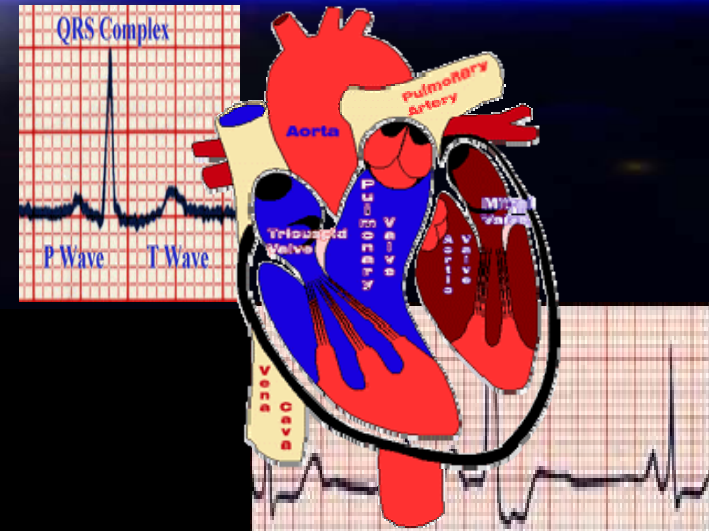
# Space Flight Bone Mineral Index





# Human Space Flight Research Improves Health on Earth

- **Medical telemetry** developed to monitor astronauts was incorporated into the standard care for Intensive and Cardiac Care Units (ICUs and CCUs). Commonly monitored parameters via telemetry are EKG, body temperature, blood pressure, respiration, and oxygen saturation. In the CCU, after this was incorporated, death rates were reduced from roughly 30% to roughly 7% for people who had suffered heart attacks (*the extent of this reduction that is attributable to NASA is not able to be quantified*).
- **Bone density measurement** -- NASA catalyzed the development of the bone measurement devices that are now used for the diagnosis and following therapy to prevent fractures in older people with osteoporosis.



Bone Mineral Density (BMD) is best assessed by computerized central densitometry (DEXA Scan) comparing the spine and hip to peak bone mass at age 30 (T-Score).

